3.2 Geology, Soils and Mineral Resources

REGIONAL SETTING

The I'SOT geothermal project is located in on the southwestern edge of the Modoc Plateau, a physiographic and geological province in northeast California and southeastern Oregon. It is bounded by the Basin and Range Province to the east and the Cascade Range to the west, northwest and southwest and the Columbia Plateau to the north.

The Modoc Plateau is a relatively flat and high (1,200 to 1,500 m (4,000 to 5,000 ft) above sea level (asl)) plain. It covers approximately 27,750 km^2 (10,000 mi^2) of the southwest corner of the Columbia Plateau.

Miocene pyroclastic basalts of the Cedarville Series formed the Modoc Plateau. In the Pliocene, these basalts were faulted along basin and range-type north-south trending extensional faults (Figure 3.2-1, Fault Zones of the Alturas Region). Deposition of the Pliocene Warren Basalt flows followed this faulting episode. These 30 m thick flows filled valleys and grabens created by the preceding faulting episode and formed the flat surface that dominates regional topography. Some sediments and tuffaceous layers interbed these flows.

This sequence is broken by discontinuous north to northwest trending normal faults associated with regional extension in the Basin and Range. Tectonically, the Modoc Plateau is similar to the Basin and Range except that: the faults are less active; faulting is more discontinuous; and there is no evidence of Holocene displacement on the northwest-trending faults that may comprise extensions of the Basin and Range Walker Lane belt (see Figure 3.2-1). While many faults within the Modoc Plateau display evidence of Quaternary displacement, Holocene displacement is limited to the western area, adjacent to the Cascade Range where Hat Creek, McArthur and related faults constitute a N10°W zone 30 km wide by 90 km long which appears to have been active in the latest Pleistocene to Holocene.

Volcanism in the region is dominated by the Cascade Range to the west from Mt. Shasta to Medicine Lake Highlands to Mt. Lassen, which was historically active (1914-1917). Extensive and currently active hydrothermal systems are related to both Medicine Lake and Mt. Lassen.

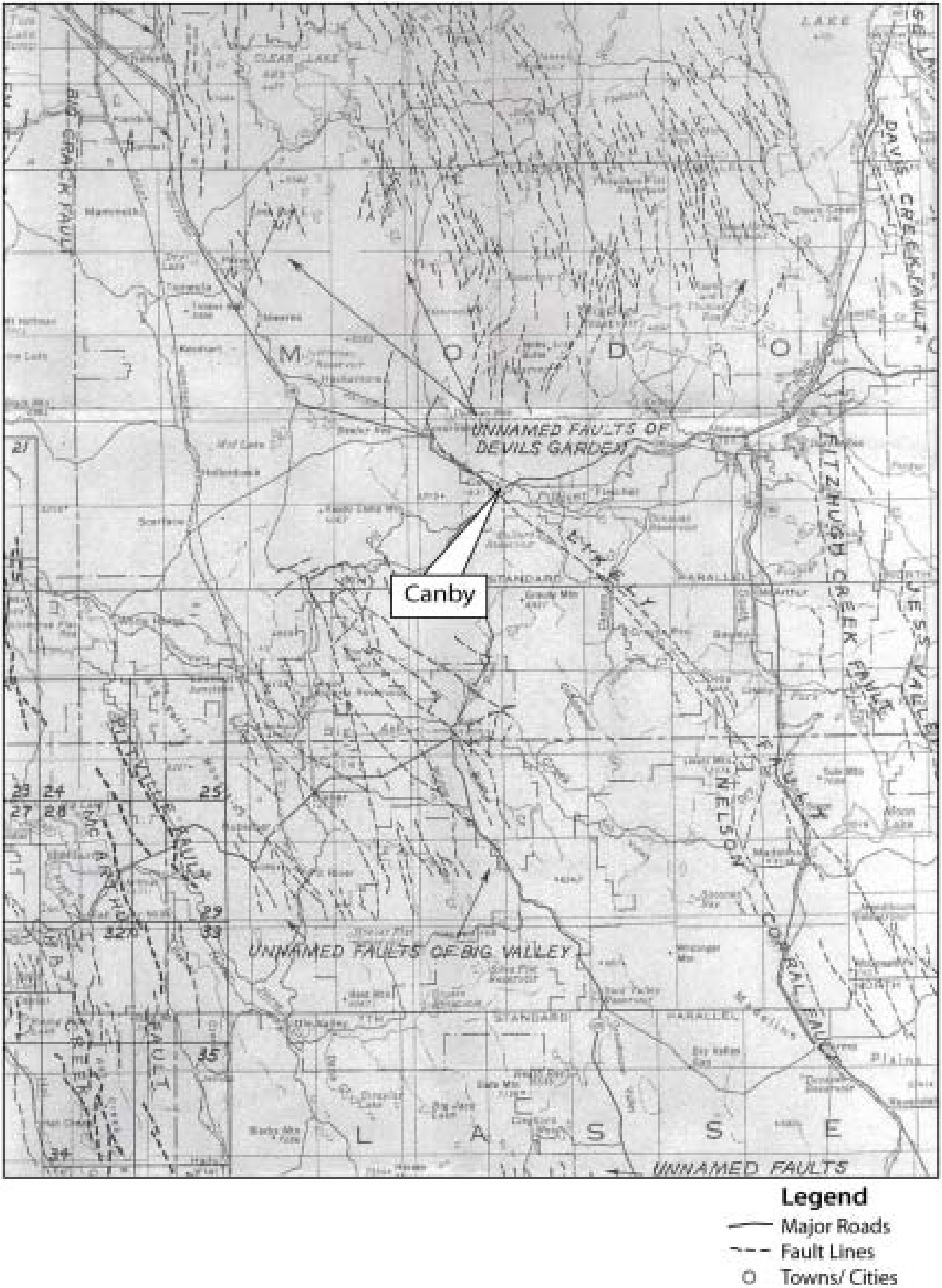
In addition to the large high temperature systems related to Cascade volcanism, the I'SOT site lies within a region of moderate to low temperature hydrothermal activity. From the Surprise Valley system to the east, which appears to be related to deep circulation along the Basin & Range faulting in that valley, to warm water resources just a few miles away, in Alturas and Kelly Hot Springs. These hydrothermal resources appear to reflect regional high heat flow and faulting, and may be related to the regional tectonic location between the Basin and Range and the Cascade Range.

Local Site Geology

The project site is located in Warm Springs Valley, an east-west river valley (elevation) that cuts the elevated Modoc Plateau (4,000-6,000 ft asl) (CDMG 1991). The Pit River flows through the center of the valley.

Relatively flat-lying Modoc Plateau volcanics and volcanic sediments dominate the geology of the site. Structural displacement of the volcanics is minimal in the local vicinity of the project site. Although the trace of Likely Fault cuts through the Canby area (see Figure 3.2-1), no local displacement or recent seismic activity has been documented (CDMG 1991). The Likely fault extends over 50 miles, which may

Figure 3.2-1: Fault Zones of the Alturas Region



SOURCE: CDMG 1991

be an extension of the Walker Lane Basin and Range extensional fault system, and appears to have significant strike-slip horizontal offset. This fault which may correlate to a regional northwest/southeast structural trend with at least some component of lateral or strike slip motion (Duffield and Fournier, 1974). Additionally, there are no active Alquist-Priolo fault zones within the vicinity of the project site.

Soils at the ground surface of the site (see below) are underlain by alluvium to approximately 40 feet below ground surface (bgs). The alluvium is underlain by over 2,000 feet of fine-grained tuffs (volcanic ash) and lahars (volcanic mud flows) probably of the Alturas Formation. These clay-rich sediments are interrupted by: a thin (less than 10 ft) lava flow between 890 and 900 ft bgs, and a lacustrine sand (probably volcanic) layer between 630 and 1,680 ft bgs. Below 1,950 ft bgs the tuffs are lithified and fractured.

The geothermal fluid is encountered in the fractured permeability within the lithified tuffs below 1,950 to the total depth of 2,100 ft bgs. Minor alternation including chlorinization of clays and silica deposition throughout the section reflects the elevated temperature gradient (7 degrees F/100ft), which will be discussed below in the section describing the geothermal resource.

Soils

Soils in Modoc County are a valuable natural resource, supporting a vital agricultural economy. Some of these soils (SCS Number 106, 119 and 176[1]) meet the criteria for farmland of statewide importance as outlined in the U. S. Department of Agriculture's land inventory and monitoring (LIM) Project for the Alturas Area.

The prominent soil type in the project area is the Pit Series (SCS Number 176). The Pit series includes silty clay loams and clays on 0 to 2 % slopes and 2 to 5% slopes, respectively. It consists of slowly draining soils on flood plains and lake basins. The available water capacity is 9.5 to 11 inches (NRCS 1980). Runoff is typically slow and there is no hazard of erosion. This soil is suitable for cultivated crops, typically irrigated for pasture or alfalfa, requires additional procedures to overcome soil limitations, and is not suitable for intensive agriculture. Other soils include the Barnard (SCS Number 106), a gravelly loam and the Daphnedale (SCS Number 119), a loam on 2 to 9% slopes.

The geothermal well located in Canby is located on Barnard gravelly loam. It is common on older terraces and alluvial fans throughout Warm Springs Valley and the Alturas Basin. Runoff is considered medium and the hazard of erosion is moderate. Available water capacity is 4.0 to 5.5 inches. Range and Pastureland are primary uses of this soil.

The Daphnedale Series to the south consists of well-drained soils on old lake terraces and escarpments. The Daphnedale loam has slow permeability, runoff is medium and the hazard of erosion is moderate. This soil is used for pasture, dryland grain and less commonly irrigated hay.

[1] This Unit is of statewide importance if protected from flooding.

Table 3.2-1: Soil Types for the Project Area

Soil Unit Names (Soil Conservation Services, SCS Number)	Project Facility	Infiltration or Runoff Potential	Erosion Hazard Rating (EHP)	Erosion Factor (K)	Storie Index[1]	Land Capability Index[2]
Pit silty clay loam (176) (0-2% slopes)	Pit River Basin	Slow	Low	0.20	13	IIIw-5
Barnard gravelly loam (106) (0-9% slopes)	Town of Canby	Medium	Moderate		7	IIIe-3
Daphnedale loam (119) (2-9% slopes0	Western Canby	Medium	Moderate		24	IVe-1

[1] Storie Index- suitable for intensive agriculture without irrigation is 760

[2] Land Capability Index: III: suitable for cultivation but requires additional procedures to address soil limitation; IV: suitable for rangeland or pastureland

SOURCE: NRCS 1980

The discharge line traverses land characterized by the Pit Series Soils.

Unique Geologic Features

There are no unique geologic features in the project area.

Topography

The project site lies in the Warm Springs Valley, a topographic low within otherwise elevated and flat-lying Modoc Plateau. The elevation of the valley ranges from 4,400 ft to 4,300 ft and has been carved and widened by the alternating erosion and alluvial deposition of the Pit River bed, which wanders across the floor of the valley. Plateaus and hills surround the valley with elevations between 4,900 ft and 4,400 ft.

GEOLOGIC HAZARDS

Seismicity

The project area is not located in an area of historically high seismic activity; there are no recently (Holocene) active faults within close proximity to the project area. The closest fault that is believed to be capable of producing a seismic event of a magnitude 5.5 or greater on the Richter scale is the Mayfield Fault, located approximately 38 miles (61 kilometers) west of the project site, in Siskiyou County. The Likely Fault extends through the project area, but no Holocene activity has been recorded and therefore the project area is not identified as an Alquist-Priolo zone of seismic risk. To date, no earthquakes over 5.5 on the Richter scale have been recorded in Modoc County since 1769, and Modoc County lies in the lowest rated area in the State of California for earthquake activity (CDMG 2002). As a result, a significant seismic event that could result in liquefaction, ground shaking and/or surface rupture near the project area is not likely.

Liquefaction

Liquefaction occurs when water-saturated granular material is transformed from a solid state to a semi-liquid state because of an increase in the pore-water pressure caused by intense shaking. Liquefaction occurs as a result of the simultaneous occurrence of a combination of conditions. These include: 1) seismic activity to induce intense shaking, 2) loose, unconsolidated coarse-grained soils and 3) high water table. Liquefaction has not been observed in Modoc County.

Subsidence

Land subsidence is the lowering of the land-surface elevation from changes that take place underground. Common causes of land subsidence from human activity are pumping water, oil, and gas from underground reservoirs; dissolution of limestone aquifers (sinkholes); collapse of underground mines; drainage of organic soils; and initial wetting of dry soils (hydrocompaction). Generally, subsidence occurs in areas where there are sedimentary basins filled with unconsolidated sands, silts, clays, and gravels. Localized subsidence in the project area is unlikely due to the strength of the underlying volcanic bedrock (USFS and BLM 1994).

Volcanism

The Modoc Plateau area has experienced at least 4 volcanic eruptions in the past 1,500 years and the U.S. Geological Society has identified the area as one where another eruption is possible. However, the areas of active volcanism are significantly west of the site. Two recently active volcanoes are located west of the project site. Mount Shasta, located approximately 50 miles northwest of Canby, has erupted three times in the past 750 years, and the chances of an eruption in any given decade are 1 in 25 or 30 (USFS 1994a). Mount Lassen is situated approximately 130 miles (216 km) south to southwest of Canby. Three episodes of volcanism have occurred at the Lassen volcanic center in the past 1,100 years. These are the complex eruption at Chaos Crags, the eruptions at Cinder Cone, and the summit eruptions of Lassen Peak in 1914-1917 *(Clynne, 1990, IN: Wood and Kienle)*. Due to the distance to these potential eruptive centers, the most likely effect of volcanism at the project area would be in the form of wind-blown ash. Given the prevailing winds from the southwest, the project area could be affected by wind-blown transport of eruptive material from the Lassen area (see Figure 3.2-1).

Slope Stability/Landslides

Active landslides and slump and earthflow deposits are rare in the rock types found in the project area. Most of the soils in the project area are shallow to moderately shallow, with low potential for slope stability hazard. The USFS characterized slopes of greater than 30 percent as having a high risk of slope movement however; there are no slopes within the project area of this magnitude.

Mineral Resources

Modoc County contains a number of mineral resources including: cinders, pumice, pumicite, and crushed stone. Lakebed deposits include peat, diatomia and salt. Due to high extraction and transportation costs, the production of many of the resources in this region has been declining for many years. The principal mineral resources near Canby are two volcanic cinders just south of Duncan Reservoir. Cinder cones in western Modoc County have been great sources of volcanic cinders since the early 1930s. Today the cinders are primarily used for road pavement (Modoc County General Plan).

Mineral Rights

The geothermal well is located on the boundary between Assessor's Parcel No. 017-080-25 and Assessor's Parcel No. 017-080-56. The US General Land Office issued to the primary owner of Assessor's Parcel No. 017-080-25 a Land Patent (Certificate No. 2444), which granted mineral rights thereto (US General Land Office 1891). Assessor's Parcel No. 017-080-56 was first purchased by a private party in 1937. Land Patent No. 1092806, which granted to the owner all rights including mineral rights thereto, was issued in 1937 (US General Land Office 1937). Mineral rights on both sides of the well have been relinquished from public ownership to the private landowners. Ownership of the land and consequently all mineral rights thereto has since been transferred to subsequent owners. I'SOT, Inc. is the current title holder for the land on which the well is located. The Bureau of Land Management (BLM) Alturas Field Office has stated that there are no federal government claims to minerals in Township 42N, Range 9E, Section 25, MDB&M, on which the well is located (Singleton 2002, personal communication).

REGULATORY SETTING

State/Local

The Alquist-Priolo Special Studies Zones Act, which was enacted by the State of California in 1972 and renamed the Alquist-Priolo Earthquake Fault Zoning Act in 1993, was passed to prevent the construction of buildings used for human occupancy on the surface trace of active faults. The act requires the State Geologist to delineate earthquake fault zones by regulation along active faults within the state and to issue appropriate maps. For the purposes of this Act, an active fault is one that has moved in the last 11,000 years (Holocene time) (CDMG 1996).

The State of California has General Plan Guidelines, which can be used by counties and cities as a standard in developing their own General Plans. The General Plan Guidelines include a safety element section for the protection of the community from any unreasonable risks. Included in these risks are seismically induced surface rupture, ground shaking, ground failure, slope stability leading to mudslides and landslides, subsidence and other geologic hazards.